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THE PERPLEXING CONTINUUM SLOPE OF MARS: EFFECTS OF THIN FERRIC COATINGS AND VIEWING GEOMETRY;

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Introduction: One of the most interesting and perhaps most perplexing features of martian reflectance spectra is a decrease of reflectance toward long wavelengths observed for many surface terrains. This spectral feature (hereafter referred to as the continuum slope) is most commonly associated with darker martian materials and has been observed both with spot-reflectance techniques (e.g., 1) and also with the French imaging spectrometer, ISM, experiment aboard the Phobos spacecraft (2). Although atmospheric dust may contribute somewhat to the slope of some martian spectra (3), it has convincingly been shown that thin ferric coatings on dark basaltic substrates produce slopes in the laboratory similar to what is observed for Mars (4). The goal of the present study is to evaluate the effects of ferric coatings more thoroughly and determine whether differences in viewing geometry, in addition to variations of the ferric coating thickness, produce continuum slopes comparable to those observed for Mars. The experiment was designed to constrain interpretations of variations in continuum slope observed for Mars, specifically the continuum slope variations which define several spectral annuli on the flanks of Olympus Mons, observed in the ISM imaging spectrometer data. The ISM Olympus Mons data reveal that the rings, seen as alternating brighter and darker reflectance in Viking data, correspond to annuli of alternating shallower and steeper continuum slope (5).

Experimental procedure: Small slabs of identical thickness were cut from the interior portion of a large hand sample of basalt from Taos, New Mexico. The slabs were roughened with 400 grit to minimize diffraction from irregularities on the surface and then ultrasonically cleaned. Spectra were obtained of several slabs cut from different areas of the rock to ensure that the spectral properties of the hand sample were spatially constant. All spectra were obtained with the RELAB spectrometer at Brown University (6).

Hematitic material from Mauna Kea, Hawaii was crushed and wet sieved to <25 micron size and then suspended in ethanol to separate very fine grains from the bulk. The collected suspension average grain size was 2-3 microns. Different thicknesses of ferric coating were deposited on the basalt slabs by suspending different amounts of the ferric material in ethanol and then pouring the suspension into a container in which the grains settled evenly onto a slab as well as a glass slide as the ethanol evaporated. Using a binocular petrographic microscope, coating thickness was calculated by first focussing upon the surface of the coating deposited on the glass slide, then focussing upon the surface of the slide itself at the bottom of a knife-edge scribe in the coating and measuring the vertical distance between the two points of focus. After the samples were prepared, spectra were taken at several different viewing geometries (both forward and backward scattering) listed in the table below. Letters (a-i) refer to spectra presented in Figures 1 and 2 and for data obtained at those parameters.

	Viewing geometry (incidence,emergence,phase)				
Coating thickness (μm)	30,0,30	30,60,30	0,60,60	55,40,15	40,-50,90
0	a	x	x	x	x
4.3	b	x	x	x	x
6.3	c				x
11.0	d	x	x	x	x
17.3	e				
37.5	f				x
225.0	g	h	x	x	i

Results: Several factors involved in the cause of continuum slope (calculated as the change of reflectance per micron between 1.68 and 2.48 microns) are identified in this study. First, differences in thin ferric oxide coating thickness contribute to variations of continuum slope. Spectra of several different thickness samples measured at the standard RELAB viewing geometry, i=30° e=0°, are shown in Figure 1 along with the spectrum of a loose powder of the ferric material. The continuum slope is thought to occur because the ferric coating is transparent at longer wavelengths (4). Therefore, with optically thin coatings, the dark underlying basalt dominates the long wavelength region of the spectrum while the bright ferric powder dominates the short wavelength region. Together, these account for the decrease in reflectance toward longer wavelengths. Note in Figure 1 that as the thickness of sample increases, the slope becomes more negative until the ferric coating starts to become optically thick at long wavelengths.

The continuum slope of a sample is also affected by several variables associated with surface texture and viewing geometry. Perhaps the most intriguing contributor to negative continuum slope appears to be differential forward scattering. In Figure 2 are shown spectra of a sample with an optically thick ferric coating (225 microns of coating thickness) measured at several different viewing geometries. Note that two of the

spectra (h and g) both exhibit a negative continuum slope, whereas the continuum of the spectrum at a forward scattering geometry (i) is almost flat. As the coating is optically thick, transparency at long wavelengths of thin ferric coatings on a dark substrate cannot explain the continuum slope. Instead, for the thick ferric coating there appears to be an increase in forward scattering (and a decrease in backscatter radiation) at longer wavelengths. This results in a negative continuum slope when observed from backscatter geometries. Variations of continuum slope are also observed for samples with prepared differences of surface texture (packed versus loose), suggesting that surface texture, forward scattering and continuum slope are interrelated. The smooth textural nature of the ferric coatings (a crust created by liquid settling when producing the more thickly coated samples) clearly influences the continuum slope at backscattering geometries. Further analysis of the textural effects on continuum slope and the possible link to duricrust on Mars is underway.

In summary, at least three factors contributing to continuum slope can be identified in this study -- ferric coating thickness, viewing geometry, and surface texture. Because the Olympus Mons spectral annuli were observed at nearly constant backscatter geometries in the ISM data, with only slight viewing variations due to the volcano's flank slopes, the difference of continuum slope between annuli probably cannot be explained by viewing geometry alone. This suggests that the variation of some fundamental surface characteristic(s), such as ferric dust/rind thickness or surface texture, is the cause of the Olympus Mons spectral annuli observed in the ISM imaging spectrometer data. Further studies currently underway include an examination of the effects on continuum slope of different particle size ferric dust, ferric rinds and coating texture. The primary objective is an in depth exploration of the geologic significance of the spectral annuli around Olympus Mons.

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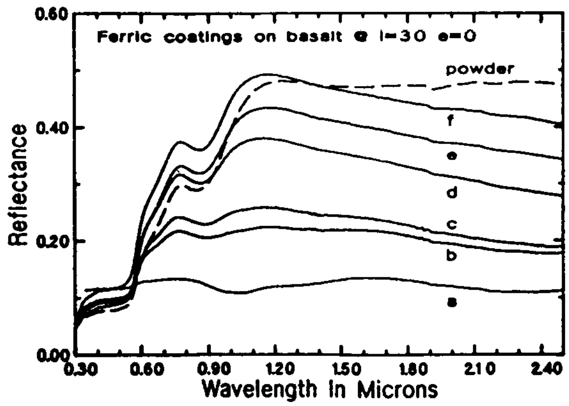

Fig. 1: Spectra of loose ferric powder and of various thicknesses of ferric coating on basalt at i=30° e=0°. Letters refer to the table on the previous page.

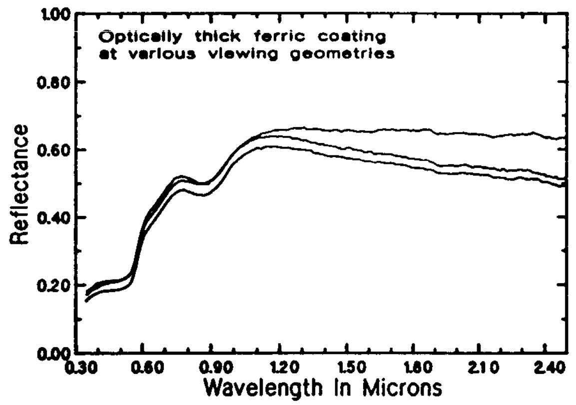

Fig. 2: Spectra of an optically thick ferric coating on basalt at various viewing geometries. Letters refer to the table on the previous page. Spectrum i is at a forward scattering geometry.